MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2017/2018

ETN3136 – DIGITAL COMMUNICATIONS

(TE/MCE)

21 OCTOBER 2017
9:00 A.M – 11:00 A.M
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 8 pages including cover page with **4** Questions only.

2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Given that a data stream is to be transmitted on a channel contaminated with Gaussian white noise. The data stream has bit rate, R_b = 20 kbit/s and is to be transmitted at signal-to-noise ratio (S/N) of 10 dB. The channel is having bandwidth, B = 4 kHz. Is it possible to achieve error-free transmission? Justify your answer.

[6 marks]

(b) Differentiate between analog and digital communication systems in terms of their resistance against noise.

[4 marks]

(c) Figure Q1(c) shows the impulse response of a linear time invariant channel.

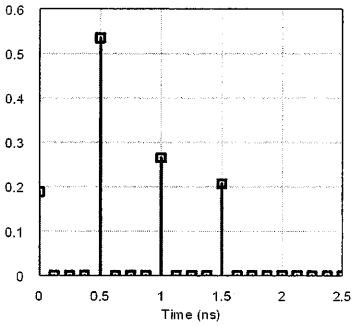

Figure Q1(c)

(i) Define the term ***impulse response*** of a communication channel.

[2 marks]

(ii) Is the impulse response in Figure Q1(c) showing an ideal distortionless channel? If not, name the type of channel that it shows and sketch the impulse response of an actual ideal distortionless channel.

[3 marks]

(iii) A data stream with bit rate of 2 Gbps is transmitted on this channel. Comment on the error rate performance of this system.

[3 marks]

(d) Given that $w(t)$ has the Fourier transform of

$$W(f) = \frac{1}{1 + j2\pi f}$$

Find the Fourier transform for the signal $x(t) = w(1-t)$.

[7 marks]

Continue...

Question 2

(a) Sampling is used to convert an analog signal into a digital signal.

(i) A 1 kHz sine wave is naturally sampled at 4 kHz sampling rate with each sampling pulse width, $\tau = 50$ μs. Sketch the naturally sampled waveform.

[3 marks]

(ii) The time domain signal $m(t)$ and its spectrum $M(\omega)$ is shown in Figure Q2(a). Assume no aliasing occurs, sketch the instantaneously sampled signal and its spectrum.

[5 marks]

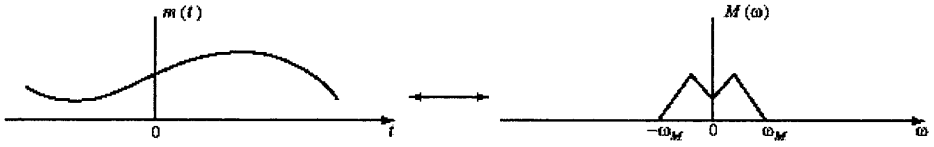

Figure Q2(a)

(b) A binary stream 0101011100 is transmitted using line coding. Sketch the transmitted waveforms of the following line codes for the given binary stream:

(i) Unipolar non return-to-zero (NRZ)

[2 marks]

(ii) Polar NRZ

[2 marks]

(iii) Unipolar return-to-zero (RZ).

[2 marks]

(c) An analog signal is modulated into PCM pulses and transmitted over a channel that is band limited to 70 kHz. Assume that the PCM has 16 quantization levels and the raised cosine function with a roll-off factor of $r = 0.4$ is used for pulse shaping. Also, assume that each PCM pulse can take 4 possible levels.

(i) Find the maximum bit rate, R_b, for this system.

[3 marks]

(ii) Find the maximum bandwidth of the analog signal.

[3 marks]

(iii) Repeat (c)(i) and (c)(ii) for a PCM pulse having 8 possible levels.

[5 marks]

Continue...

Question 3

(a) Pulse shaping at the transmitter is utilized to control the amount of intersymbol interference at the receiver side. The impulse response of the pulse shaping takes the form of a sinc function $h_e(t) = \sin \pi f_s t / \pi f_s t$.

(i) Define the meaning of intersymbol interference.

[3 marks]

(ii) Using a suitable diagram, explain whether intersymbol interference will be present at the receiver if we assume that there is no error in the sampling instants.

[6 marks]

(b) Assume that a QPSK signal is used to send data at a bit rate of 40 Mbits/s over a channel with bandwidth of 30 MHz.

(i) If raised cosine filter is used, calculate the required roll-off factor, *r*.

[3 marks]

(ii) Calculate the roll-off factor, *r*, if the bit rate is increased to 70 Mbit/s. Comment on your answer.

[3 marks]

(iii) Using the obtained roll-off factor in (b)(i), calculate the required bandwidth if 16-PSK modulation is used to send data at the same bit rate of 40 Mbits/s. Deduce the percentage bandwidth saving as a result of this.

[4 marks]

(c) Orthogonal frequency division multiplexing (OFDM) modulation scheme is another method to combat intersymbol interference. Using a suitable diagram, explain how OFDM is able to mitigate intersymbol interference.

[6 marks]

Continue...

Question 4

(a) A linear time invariant electronic system is contaminated with Gaussian noise having root mean square (rms) noise voltage of 1 mV. Compute the probability of which the instantaneous noise voltage of the system lies between –3 mV and +3 mV.
(Hint: Refer to Appendix II.)

[7 marks]

(b) A binary stream with signal values either a_0 or a_1 is transmitted through a channel contaminated with additive white Gaussian noise. The probability density function (pdf) of the two signal values is shown in Figure Q4(b). Show that the probability of error is given by $P_e = Q\left(\frac{a_1 - a_0}{2\sigma}\right)$, where $Q(\bullet)$ is the Q-function in Appendix I and σ is the noise standard deviation.

[10 marks]

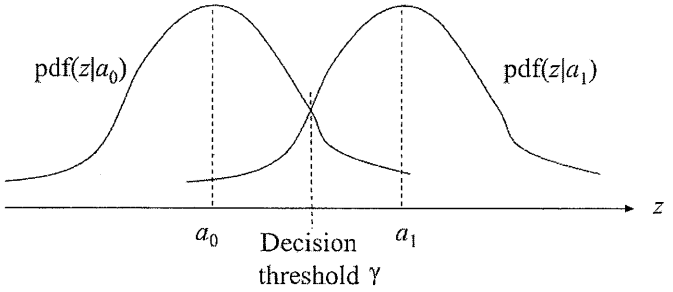

Figure Q4(b)

(c) The signal-to-noise ratio (SNR) at the output of a receiver is maximized by means of a matched filter.

(i) State the relationship between the impulse response of a matched filter and its input signal.

[1 mark]

(ii) Explain how an integrate-and-dump circuit implements a matched filter.

[3 marks]

(iii) Sketch the output signals of the integrate-and-dump circuit and the matched filter, respectively, for an input signal shown in Figure Q4(c).

[4 marks]

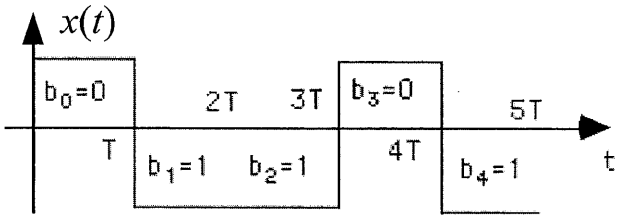

Figure Q4(c)

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Appendix I

Tabulated values of Q-function

The Q Function (Gaussian Distribution with $\mu = 0$ and $\sigma = 1$)

$$Q(a) = \int_a^\infty \frac{1}{\sqrt{2\pi}} e^{\frac{-x^2}{2}} dx \qquad Q(a) \cong \frac{1}{a\sqrt{2\pi}} e^{\frac{-a^2}{2}} \text{ for } a \geq 3$$

	3rd Significant Digit									
a	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
0.7	0.2420	0.2389	0.2358	0.2327	0.2297	0.2266	0.2236	0.2207	0.2177	0.2148
0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
1.2	0.1151	0.1131	0.1112	0.1094	0.1075	0.1057	0.1038	0.1020	0.1003	0.0985
1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
3.0	0.0014	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002

$Q(a)$	a
10^{-4}	3.73
5×10^{-5}	3.90
10^{-5}	4.27
5×10^{-6}	4.43

$Q(a)$	a
10^{-6}	4.76
10^{-7}	5.20
10^{-8}	5.61
10^{-9}	6.00

Continue…

Appendix II

Tabulated values of error function

$$\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2}\, dt$$

	Hundredths digit of x									
x	0	1	2	3	4	5	6	7	8	9
0.0	0.00000	0.01128	0.02256	0.03384	0.04511	0.05637	0.06762	0.07886	0.09008	0.10128
0.1	0.11246	0.12362	0.13476	0.14587	0.15695	0.16800	0.17901	0.18999	0.20094	0.21184
0.2	0.22270	0.23352	0.24430	0.25502	0.26570	0.27633	0.28690	0.29742	0.30788	0.31828
0.3	0.32863	0.33891	0.34913	0.35928	0.36936	0.37938	0.38933	0.39921	0.40901	0.41874
0.4	0.42839	0.43797	0.44747	0.45689	0.46623	0.47548	0.48466	0.49375	0.50275	0.51167
0.5	0.52050	0.52924	0.53790	0.54646	0.55494	0.56332	0.57162	0.57982	0.58792	0.59594
0.6	0.60386	0.61168	0.61941	0.62705	0.63459	0.64203	0.64938	0.65663	0.66378	0.67084
0.7	0.67780	0.68467	0.69143	0.69810	0.70468	0.71116	0.71754	0.72382	0.73001	0.73610
0.8	0.74210	0.74800	0.75381	0.75952	0.76514	0.77067	0.77610	0.78144	0.78669	0.79184
0.9	0.79691	0.80188	0.80677	0.81156	0.81627	0.82089	0.82542	0.82987	0.83423	0.83851
1.0	0.84270	0.84681	0.85084	0.85478	0.85865	0.86244	0.86614	0.86977	0.87333	0.87680
1.1	0.88021	0.88353	0.88679	0.88997	0.89308	0.89612	0.89910	0.90200	0.90484	0.90761
1.2	0.91031	0.91296	0.91553	0.91805	0.92051	0.92290	0.92524	0.92751	0.92973	0.93190
1.3	0.93401	0.93606	0.93807	0.94002	0.94191	0.94376	0.94556	0.94731	0.94902	0.95067
1.4	0.95229	0.95385	0.95538	0.95686	0.95830	0.95970	0.96105	0.96237	0.96365	0.96490
1.5	0.96611	0.96728	0.96841	0.96952	0.97059	0.97162	0.97263	0.97360	0.97455	0.97546
1.6	0.97635	0.97721	0.97804	0.97884	0.97962	0.98038	0.98110	0.98181	0.98249	0.98315
1.7	0.98379	0.98441	0.98500	0.98558	0.98613	0.98667	0.98719	0.98769	0.98817	0.98864
1.8	0.98909	0.98952	0.98994	0.99035	0.99074	0.99111	0.99147	0.99182	0.99216	0.99248
1.9	0.99279	0.99309	0.99338	0.99366	0.99392	0.99418	0.99443	0.99466	0.99489	0.99511
2.0	0.99532	0.99552	0.99572	0.99591	0.99609	0.99626	0.99642	0.99658	0.99673	0.99688
2.1	0.99702	0.99715	0.99728	0.99741	0.99753	0.99764	0.99775	0.99785	0.99795	0.99805
2.2	0.99814	0.99822	0.99831	0.99839	0.99846	0.99854	0.99861	0.99867	0.99874	0.99880
2.3	0.99886	0.99891	0.99897	0.99902	0.99906	0.99911	0.99915	0.99920	0.99924	0.99928
2.4	0.99931	0.99935	0.99938	0.99941	0.99944	0.99947	0.99950	0.99952	0.99955	0.99957
2.5	0.99959	0.99961	0.99963	0.99965	0.99967	0.99969	0.99971	0.99972	0.99974	0.99975
2.6	0.99976	0.99978	0.99979	0.99980	0.99981	0.99982	0.99983	0.99984	0.99985	0.99986
2.7	0.99987	0.99987	0.99988	0.99989	0.99989	0.99990	0.99991	0.99991	0.99992	0.99992
2.8	0.99992	0.99993	0.99993	0.99994	0.99994	0.99994	0.99995	0.99995	0.99995	0.99996
2.9	0.99996	0.99996	0.99996	0.99997	0.99997	0.99997	0.99997	0.99997	0.99997	0.99998
3.0	0.99998	0.99998	0.99998	0.99998	0.99998	0.99998	0.99998	0.99999	0.99999	0.99999
3.1	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999
3.2	0.99999	0.99999	0.99999	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000

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Appendix III

Fourier Transform Operations

Operation	$g(t)$	$G(\omega)$
Addition	$g_1(t)+g_2(t)$	$G_1(\omega)+G_2(\omega)$
Scalar multiplication	$kg(t)$	$kG(\omega)$
Symmetry	$G(t)$	$2\pi g(-\omega)$
Scaling	$g(at)$	$\frac{1}{\lvert a\rvert}G\left(\frac{\omega}{a}\right)$
Time shift	$g(t-t_o)$	$G(\omega)e^{-j\omega t_o}$
Frequency shift	$g(t)e^{j\omega_o t}$	$G(\omega-\omega_o)$
Time convolution	$g_1(t)*g_2(t)$	$G_1(\omega)G_2(\omega)$
Frequency convolution	$g_1(t)g_2(t)$	$\frac{1}{2\pi}G_1(\omega)*G_2(\omega)$
Time differentiation	$\frac{d^n g}{dt^n}$	$(j\omega)^n G(\omega)$
Time integration	$\int_{-\infty}^{t} g(x)dx$	$\frac{G(\omega)}{j\omega}+\pi G(0)\delta(\omega)$

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